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Toxic and Repellent Sprays for the Control of Elm Bark Beetles

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CONTENTS

INTRODUCTION

One very important phase of the program for the eradication of the Dutch elm disease is the control of its two principal insect vectors, *Scolytus multistriatus* (Marsh.) and *Hylurgopinus rufipes* (Eich.). Both these bark beetles breed only in dead or dying elm wood, but in their feeding activities they may transmit the disease organism to sound trees. The principal means of control, therefore, has been the removal and burning of dead or dying elm wood from within the area in which the disease is known to occur. This method of control, although effective, has been both costly and laborious, and in addition has caused the loss of thousands of cords of fuel wood.

Experiments with chemical sprays for the prevention of insect injury to green logs were reported by Craighead [2] in 1922. Since then further studies of this problem have been made by other members of the Division of Forest Insect Investigations of the Bureau of Entomology and Plant Quarantine, and the results have been sum-

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[1] The writer acknowledges the assistance of F. C. Craighead, in charge of the Division of Forest Insect Investigations, and of C. W. Collins, of the Morristown, N. J., laboratory of the Bureau, in the planning and execution of these experiments. He is also indebted to E. G. Brewer, in charge of the Federal Dutch elm disease eradication unit, for his cooperation in furnishing much of the assistance in cutting the necessary elm logs and later in stripping the bark from these logs; and to L. F. Cifrese and W. C. Baker, of the Morristown laboratory, for their very helpful assistance in the field and laboratory. The photographs are by A. E. Lantz of the Morristown laboratory.

[2] Craighead, F. C. experiments with spray solutions for preventing insect injury to green logs. U. S. Dept. Agr. Dept. Bul. 1079, 11 pp. 1922.

marized by Salman.[3] Christian[4 5] has also recently published accounts of his experiments with many chemical solutions used as preventives against damage to forest products by ambrosia and powder-post beetles. For the last 3 years this Bureau has conducted experiments with various spray solutions for the control of the bark beetle vectors of the Dutch elm disease. The results with several of these mixtures have been very encouraging. In many cases complete repellency and mortalities of 80 to 100 percent have been obtained. Limited applications of a few of these mixtures under field conditions indicate that they may be useful in controlling these bark beetles.

SPRAY MATERIALS

Four types of materials were used in preparing the spray formulas, namely, toxic or repellent agents, carriers, solvents, and emulsifiers. The materials were selected for study for various reasons, including their use by other workers, their availability, and their cost. The following list includes only the materials considered in this circular. Some of these materials are critically essential for the prosecution of the war and their use for civilian purposes under present conditions is restricted, or they may be unavailable.

Toxic or repellent agents.—(1) Naphthalene flakes, (2) crude orthodichlorobenzene, (3) chlorinated naphthalene, sold as "monochloronaphthalene," (4) diphenyl flakes, and (5) pentachlorophenol.

Carriers.—(1) Light fuel oils with Baumé gravities from 26° to 45°, and (2) water.

Solvents.—(1) Acetone, (2) toluene, and (3) xylene. (The use of naphthalene, diphenyl, or pentachlorophenol necessitated the use of a solvent before they could be mixed with a carrier.)

Emulsifiers.—When water was used as a carrier it was necessary to use an emulsifier. Most of such materials are proprietary compounds and are sold under trade names. Except for use with orthodichlorobenzene, the most effective emulsifier of those tested was found to be the sodium salt of an alkyl aryl poly ether sulfonate. A new emulsifier (a sulfonated and sulfated poly ether salt) appears to be more effective in emulsifying orthodichlorobenzene. The others tested were a modified glycol oleate and an ordinary miscible spray oil.

SPRAY FORMULAS

Although over 50 spray formulas have been tested in the course of these studies, only 19 are considered in this circular. All have been tested for their toxicity to elm bark beetles and a few of them for their repellent effects as well. Several fuel oils were tested as carriers, and as they gave equally good results, only the cheapest was used. At the head of each formula is a letter and the estimated cost per gallon of spray on the basis of 1940 prices. These formulas will henceforth be referred to by the designating letter.

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[3] SALMAN, K. A. RECENT EXPERIMENTS WITH PENETRATING OIL SPRAYS FOR THE CONTROL OF BARK BEETLES. Jour. Econ. Ent. 31: 119–123. 1938.

[4] ANONYMOUS. CHEMICAL DIPS TESTS AGAINST LYCTUS POWDER-POST BEETLES, LYCTUS PARALLELOPIPEDUS (MELSH.) AND LYCTUS PLANICOLLIS LECONTE. South. Lumberman 159: 105–109, illus. 1939.

[5] CHRISTIAN, M. B. EXPERIMENTS ON THE PREVENTION OF AMBROSIA BEETLE DAMAGE IN HARDWOODS. South. Lumberman 159: 110–112, illus. 1939.

——— LYCTUS BEETLE DAMAGE PREVENTION. SECOND REPORT ON CHEMICAL DIP TESTS AGAINST LYCTUS POWDER-POST BEETLES, LYCTUS PARALLELOPIPEDUS (MELSH.) AND LYCTUS PLANICOLLIS LECONTE. South. Lumberman 160: 47–49, illus. 1940.

Formula A—20 cents

Fuel oil	cubic centimeters	1,000
Orthodichlorobenzene	do	250

Formula B—14 cents

Fuel oil	cubic centimeters	1,000
Orthodichlorobenzene	do	125

Formula C—14 cents

Fuel oil	cubic centimeters	1,600
Orthodichlorobenzene	do	100

Formula D—24 cents

Fuel oil	cubic centimeters	1,000
Orthodichlorobenzene	do	250
Naphthalene [6]	grams	120

Formula E—18 cents

Fuel oil	cubic centimeters	1,000
Xylene	do	250
Naphthalene [6]	grams	120

Formula F—45 cents

Fuel oil	cubic centimeters	1,000
Monochloronaphthalene	do	250

Formula G—28 cents

Fuel oil	cubic centimeters	1,000
Monochloronaphthalene	do	125

Formula H—23 cents

Fuel oil	cubic centimeters	1,000
Monochloronaphthalene	do	100

Formula I—21 cents

Fuel oil	cubic centimeters	1,200
Monochloronaphthalene	do	100

Formula J—32 cents

Fuel oil	cubic centimeters	1,000
Monochloronaphthalene	do	125
Orthodichlorobenzene	do	125

Formula K—17 cents

Fuel oil	cubic centimeters	3,785
Acetone	do	300
Pentachlorophenol [7]	grams	90

Formula L—12 cents

Fuel oil	cubic centimeters	3,785
Acetone	do	150
Pentachlorophenol [7]	grams	45

Formula M—40 cents

Fuel oil	cubic centimeters	3,785
Toluene	do	700
Pentachlorophenol [8]	grams	90

Formula N—55 cents

Fuel oil	cubic centimeters	3,000
Toluene	do	700
Diphenyl [8]	grams	200
Pentachlorophenol	do	90

[6] The naphthalene was dissolved in the orthodichlorobenzene or xylene before the fuel oil was added.
[7] The pentachlorophenol was dissolved in the acetone before the fuel oil was added.
[8] The diphenyl or pentachlorophenol was dissolved in the toluene before the fuel oil was added.

Formula O—18 cents

Water	cubic centimeters	3, 785
Orthodichlorobenzene	do	946
Emulsifier [9]	do	50

Formula P—20 cents

Water	cubic centimeters	3, 785
Orthodichlorobenzene	do	946
Miscible spray oil	do	240

Formula Q—33 cents

Water	cubic centimeters	3, 785
Orthodichlorobenzene	do	946
Emulsifier [10]	do	400

Formula R—14 cents

Water	cubic centimeters	3, 200
Xylene	do	800
Emulsifier [11]	do	40
Naphthalene [12]	grams	160

Formula S—15 cents

Water	cubic centimeters	3, 200
Xylene	do	800
Miscible spray oil	do	200
Naphthalene [13]	grams	160

[9] The emulsifier (sodium salt of an alkyl aryl poly ether sulfonate) was added to the orthodichlorobenzene before the water was added.
[10] A modified diglycol oleate.
[11] The emulsifier was added to the xylene-naphthalene mixture before the water was added.
[12] The naphthalene was dissolved in the xylene before the emulsifier and water were added.
[13] The naphthalene was dissolved in the xylene before the spray oil and water were added.

EXPERIMENTAL PROCEDURE

The experimental methods employed were dependent on whether the spray formula was being tested for its repellent or toxic qualities. Therefore the procedures will be described for both the toxicity and repellency experiments.

Toxicity Experiments

With the exception of certain field applications, all treatments were applied with a knapsack-type compressed-air sprayer equipped with a disk nozzle. Sufficient spray was applied to wet thoroughly the entire bark surface of the material under treatment. Usually 5 to 10 elm logs, 5 to 8 inches in diameter, infested with *Scolytus multistriatus* or *Hylurgopinus rufipes*, or both, were treated in each test. Similar lots of infested elm logs were left untreated as checks. The bark area and age of the bark beetle brood at the time of treatment were recorded for each log. In a few cases measurements were made of the moisture content of the bark of both the treated and check logs at the time of treatment.

After the treatment both the check and sprayed logs were stored on an outdoor screened rack until the surviving bark beetle brood had matured and emerged as adults. The total emergence was determined for each log by counting the characteristic emergence holes. The bark was then stripped from each log and the number, length in millimeters, and species of each bark beetle egg gallery was recorded. From these data it was found possible to compensate for the inevitable differences in infestation found in individual logs. The results of each test were calculated as follows: The average number of emer-

gence holes for each 100 millimeters of bark beetle egg gallery was computed for all the treated logs and all the check logs in each test; then the difference between the figure for the check logs and the one for the treated logs was divided by the figure for the check logs. The result is given as percentage reduction over the check.

Repellency Experiments

The methods used in the repellency tests were similar to those described above except that uninfested elm logs suitable for bark beetle attack were used for both treatments and checks. Immediately after treatment these logs were exposed for varying periods of time in areas where the two elm bark beetles were known to occur in sufficient numbers to assure attack in suitable elm wood.

The results of these tests were obtained by stripping the bark from each log after its period of exposure and carefully counting the number of galleries of *Scolytus multistriatus* and *Hylurgopinus rufipes*. These galleries were classified as either normal or attempted. The normal galleries contained one or more living bark beetle larvae, the attempted galleries had no living larvae. The difference between the number of normal bark beetle galleries in the check logs and in the treated logs gave the measure of repellent effect of the spray mixtures. This difference divided by the number in the corresponding check gave the percentage reduction over the check.

FACTORS THOUGHT TO AFFECT RESULTS

When these studies were begun it was believed that certain of the spray mixtures reached the bark beetle larvae by penetrating directly through the bark to the larval mines. On the basis of this theory it was believed that such factors as the moisture content of the bark, the air temperature, and the age of the bark beetle brood all materially affected the results of these sprays. Since that time a few very limited experiments with stained oils have indicated that probably many of these mixtures reach the brood by entering the egg gallery through the entrance hole and diffusing through the tightly packed borings in the larval mines. The above-mentioned factors, however, have been considered in these studies and the results are given in subsequent sections.

Bark Moisture

Elm logs comparable in size, bark area, degree of infestation of *Scolytus multistriatus* and *Hylurgopinus rufipes*, and age of bark beetle brood were stored under different conditions of moisture. After various periods of time groups of these logs were sampled for the moisture content of the bark. These samples were taken by cutting 10 bark disks, 1 inch in diameter, from various sections of each log. All the samples from each section were immediately placed in tightly stoppered glass vials and weighed to the nearest milligram. After the bark disks had been weighed they were removed from the vial, placed in evaporation dishes, and dried to constant weight at 212° F. in an electric oven. The vials were dried with a clean cloth and weighed so that the moist weight of the disks could be determined. Finally the loss in weight due to desiccation, for the samples from each section, was divided by their dry weight and the result recorded as percent moisture. The results of these tests are presented in table 1.

TABLE 1.—*Relationship between bark moisture and effectiveness of sprays for the control of elm bark beetles*

Test No.	Spray formula	Total bark area	Bark moisture			Average emergence [1]		Reduction over check
			Maximum	Minimum	Average	Check	Treated	
		Square feet	*Percent*	*Percent*	*Percent*	*Number*	*Number*	*Percent*
1	Q	23.9	49.4	38.8	43.6	18.9	5.3	72.0
2	Q	25.8	52.2	46.6	49.6	16.1	2.9	82.0
3	Q	21.7	47.2	38.9	42.5	11.7	3.7	68.4
4	O	40.2	62.0	52.2	56.0	11.9	0	100.0
5	O	43.4	41.8	30.4	37.6	15.3	.3	98.0
6	O	28.9	49.0	40.8	44.6	13.0	.2	98.5
7	O	27.5	65.7	49.5	57.9	5.3	0	100.0
8	O	24.8	53.8	46.0	48.6	8.7	.7	92.0
9	O	44.0	42.7	33.4	39.4	17.8	.2	98.9
10	O	41.9	139.6	108.4	129.7	12.0	0	100.0
11	A	20.2	46.7	38.8	43.1	83.8	0	100.0
12	A	20.8	65.7	51.5	58.2	23.0	0	100.0

[1] The average emergence is for each 100 millimeters of egg gallery to compensate for differences in degree of infestation between treated and check logs.

It will be seen from the data presented in table 1 that bark moistures of from 30 to 139 percent did not significantly affect the results of spray formulas O and A. Formula Q gave poor results under all percentages of moisure.

AIR TEMPERATURE

General observations have led to the belief that air temperatures below 50° F. have deleterious effects on the results of the spray mixtures. This has been confirmed to a certain extent by the more constant results obtained at the higher temperatures.

AGE OF BARK BEETLE BROOD

In each treatment the age of the bark beetle brood was studied for its effect on the results of the spray mixture. In addition to this, a specific study was made with one spray formula. This test consisted of infesting 25 elm logs with elm bark beetles on the same day. At intervals of 3, 4, 5, and 7 weeks, 5 logs were randomly selected from this group and thoroughly sprayed with formula O. The remaining 5 untreated logs were designated as checks. The results of this study are presented in table 2. From the data presented and observations on other treatments it is evident that the age of the brood has no effect on the results of the spray.

TABLE 2.—*Effect of the age of the bark beetle brood on the toxicity of formula O*

Age of brood (weeks)	Total bark area	Average emergence [1]	Reduction over check
	Square feet	*Number*	*Percent*
3	19.5	0	100.0
4	18.0	1.5	87.3
5	16.7	0	100.0
7	20.6	.1	99.2
Check	18.2	11.8	

[1] The average emergence is for each 100 millimeters of egg gallery to compensate for difference in degree of infestation between treated and check logs.

RESULTS OBTAINED

The results obtained from these various spray mixtures have been grouped according to the objective, namely, the toxicity or repellency to the two elm bark beetles. The results of the toxicity tests have been summarized in table 3.

TABLE 3.—*Toxicity of various spray mixtures to elm bark beetles*

Formula	Number of tests	Total bark area	Total beetle emergence	Emergence per test [1]			Reduction over check		
				Maximum	Minimum	Average	Maximum	Minimum	Average
		Square feet	*Number*	*Number*	*Number*	*Number*	*Percent*	*Percent*	*Percent*
A	7	188	58	1.1	0	0.3	100.0	98.5	99.6
Checks	7	159	22,347	109.6	21.0	62.8			
B	3	35	347	13.1	0	5.5	100.0	91.0	96.2
Checks	3	71	10,779	145.1	17.6	102.6			
C	1	4	464	23.9			83.5		
Check	1	5	2,960	145.1					
D	1	15	0	0			100.0		
Check	1	9	899	17.5					
E	1	15	0	0			100.0		
Check	1	9	899	17.5					
F	7	175	227	5.0	0	1.1	100.0	93.4	98.1
Checks	7	169	8,893	76.3	5.5	37.6			
G	2	51	4	.02	.01		99.8	99.6	
Checks	2	60	1,244	5.5	5.5				
H	1	5	3	1.0			96.5		
Check	1	6	221	28.2					
I	1	6	10	1.4			95.0		
Check	1	6	221	28.2					
J	1	13	2	.02			99.9		
Check	1	9	899	17.5					
K	1	22	58	.8			98.2		
Check	1	23	1,965	44.9					
L	1	19	29	.6			98.7		
Check	1	23	1,965	44.9					
M	1	23	36	.6			98.7		
Check	1	23	1,965	44.9					
N	1	21	14	.3			99.3		
Check	1	23	1,965	44.9					
O	15	416	334	2.4	0	.5	100.0	87.3	97.6
Checks	15	309	14,886	44.9	5.3	19.5			
P	1	19	23	.4			99.0		
Check	1	36	1,041	39.8					
Q	4	102	983	5.3	1.4	3.3	96.1	68.4	79.6
Checks	4	51	4,079	36.2	11.7	20.7			
R	1	21	456	10.1			74.6		
Check	1	36	1,041	39.8					
S	1	21	21	.8			98.0		
Check	1	36	1,041	39.8					

[1] Based on average emergence per 100 millimeters of egg gallery to compensate for differences in infestation.

It will be noted from the results presented in table 3 that tests with spray formulas A, F, and O have been sufficiently replicated to make them significant. The results obtained from all other formulas are based on so few tests that they can be considered only indicative of the effectiveness of the spray mixture. In no case was the maximum emergence per 100 millimeters of egg gallery in the treated groups so great as the minimum emergence per 100 millimeters of egg gallery in the corresponding check groups.

The results of the repellency tests are presented in tables 4 and 5. It is evident from these results that elm wood can be protected from attack by bark beetles for one entire active season of the adult beetles.

TABLE 4.—*Repellent effect of formulas A and D* [1] *as sprays against elm bark beetles*

Test No.	Elm logs in sample		Period of exposure		Average normal bark beetle galleries per log			Reduction over check	
	Check	Treated with each formula	To weather	To insect attack	Check	Treated with spray A	Treated with spray D	With spray A	With spray D
	Number	*Number*	*Weeks*	*Weeks*	*Number*	*Number*	*Number*	*Percent*	*Percent*
1	4	4	10	10	80.5	0	0	100	100
2	6	[2] 6	45	20	66.5	0	0	100	100
3	6	7	52	20	1.0	.9	7.1	10	(3)
4	6	7	50	20	1.8	3.7	2.9	(3)	(3)
5	6	7	46	20	53.3	5.0	1.7	91	97
6	6	7	40	20	62.3	4.3	10.9	93	83
7	6	7	37	20	98.5	2.1	19.1	98	81
8	6	7	32	20	79.7	3.4	.9	96	99
9	6	7	28	20	142.5	13.7	35.1	90	75
10	5	7	24	20	86.8	4.9	1.7	94	98
11	6	7	20	17	11.0	0	0	100	100
12	5	7	16	13	10.6	0	0	100	100
13	6	7	11	8	14.0	0	0	100	100
14	6	7	7	4	3.8	0	0	100	100

[1] See list of formulas, p. 3.
[2] In the case of formula D only 5 logs were treated.
[3] No reduction.

TABLE 5.—*Repellent effect of various sprays against elm bark beetles*

Formula [1]	Elm logs in sample		Period of exposure		Average normal bark beetle galleries per log		Reduction over check
	Check	Treated	To weather	To insect attack	Check	Treated	
	Number	*Number*	*Weeks*	*Weeks*	*Number*	*Number*	*Percent*
B	10	10	19	19	16.1	0	100
F	5	5	21	20	6.4	0	100
G	10	10	19	19	16.1	0	100
H	4	5	20	20	3.0	0	100
I	4	5	20	20	3.0	.2	93
I	10	10	19	19	16.1	.2	99
J	5	5	21	20	6.4	.2	97
O	10	10	19	19	16.1	2.4	85

[1] See list of formulas, pp. 3 and 4.

FIELD APPLICATIONS

The laboratory tests described in the preceding pages showed certain spray formulas to be toxic or repellent to elm bark beetles. The next step was to test the applicability of these sprays under field conditions. For this purpose five 1-cord piles of freshly cut elm logs were staked in an area where both *Scolytus multistriatus* and *Hylurgopinus rufipes* were known to occur. Each pile was made up of elm logs 8 feet in length and 2 to 15 inches in diameter (fig. 1). It is believed that this type of pile presented greater than average difficulties in obtaining good spray coverage. All five piles were staked prior to the flight season of either of the two principal elm bark beetles. Two of these elm wood piles were sprayed with repellent sprays immediately after they were staked, two other piles were treated with toxic sprays after 6 weeks of bark beetle attack, and the last pile was left untreated as a check. All treatments were applied with a wheelbarrow type of sprayer (fig. 2), equipped with a nozzle capable of producing a solid stream or mist spray, and were made without handling the individual logs.

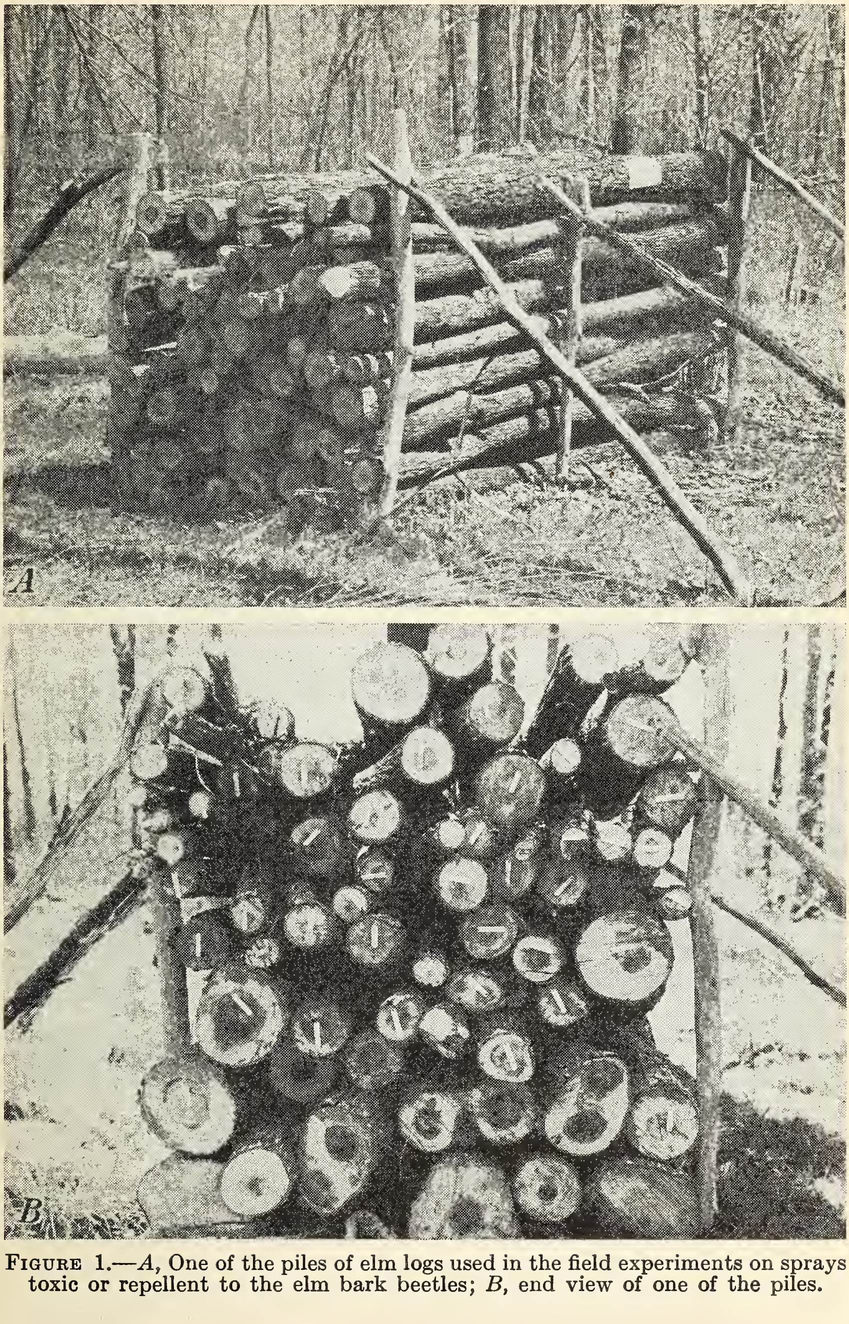

FIGURE 1.—*A*, One of the piles of elm logs used in the field experiments on sprays toxic or repellent to the elm bark beetles; *B*, end view of one of the piles.

At the end of the active season for these beetles a randomized sample of logs was examined from each pile. This examination consisted of measuring the bark area of each log in the sample and counting the emergence holes and bark beetle egg galleries. In making

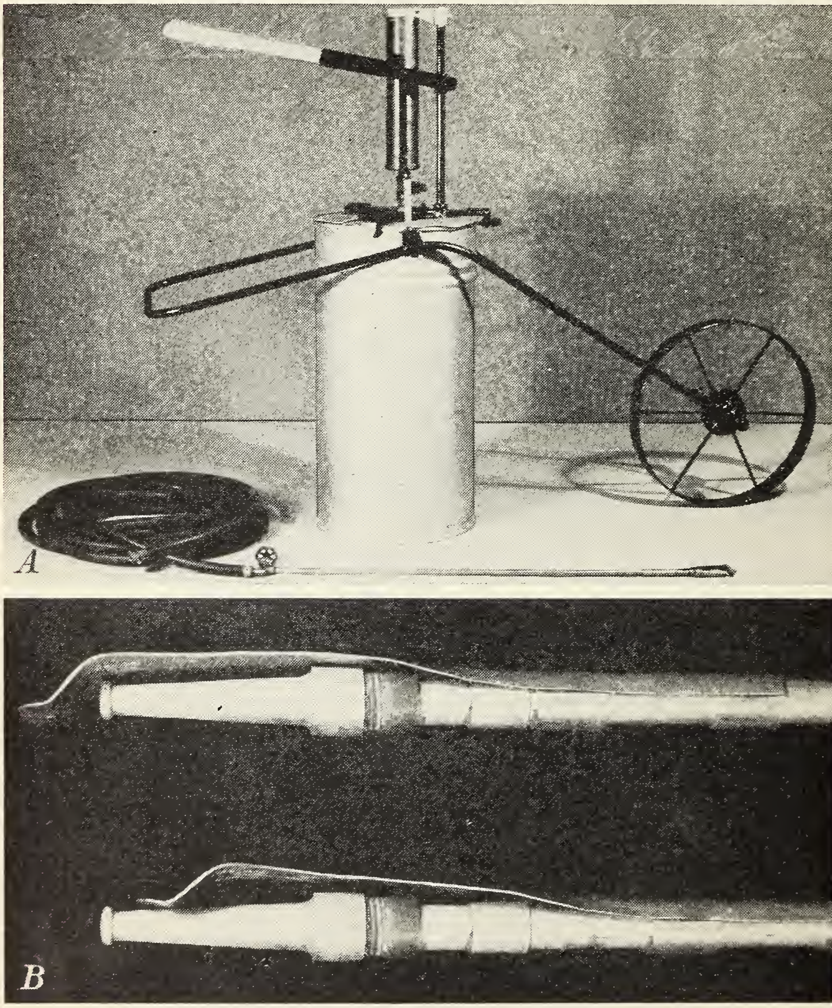

FIGURE 2.—*A*, Wheelbarrow type of sprayer used in the field application of sprays; *B*, type of nozzle used, showing attachment for mist spraying.

these counts, note was made of the location of the emergence holes or galleries in respect to the ends of the logs. The attack and development in the 2-foot terminal sections were compared with the attack and development in the 4-foot center section. These data gave some indication of the penetration of the spray into the pile.

The results, with other pertinent data from these field applications, are presented in tables 6 and 7.

TABLE 6.—*Repellent effect of sprays applied to 1-cord piles of noninfested elm wood*

Spray formula	Logs examined	Average emergence per square foot of bark area in —		Average normal egg galleries [1] per square foot of bark area in —		Reduction over check	
		Terminal 2-foot sections	Center 4-foot section	Terminal 2-foot sections	Center 4-foot section	Emergence per square foot	Egg galleries per square foot
	Number	*Number*	*Number*	*Number*	*Number*	*Percent*	*Percent*
Check	42	50.6	52.1	13.1	13.5		
A	20	2.5	.9	1.4	1.1	96.7	90.6
G	32	.3	.4	.1	.2	99.3	98.9

[1] Egg galleries of both *Scolytus multistriatus* and *Hylurgopinus rufipes*.

TABLE 7.—*Toxicity of sprays applied to 1-cord piles of infested elm wood*

Spray formula	Logs examined	Average emergence per square foot of bark area in —		Average normal egg galleries [1] per square foot of bark area in —		Average emergence per egg gallery in —		Reduction over check	
		Terminal sections	Center section	Terminal sections	Center section	Terminal sections	Center section	Emergence per square foot	Emergence per egg gallery
	Number	*Number*	*Number*	*Number*	*Number*	*Number*	*Number*	*Percent*	*Percent*
Check	42	50.6	52.1	13.1	13.5	3.9	3.9		
A	67	4.5	5.0	8.6	8.9	.5	.6	90.7	86.0
O	66	17.4	16.4	10.0	10.4	1.7	1.6	67.1	57.7

[1] Egg galleries of both *Scolytus multistriatus* and *Hylurgopinus rufipes*.

As shown, there was very little difference between the amount of attack or the accomplished control in the terminal as compared with the central sections of these elm logs.

The lower effectiveness of the toxic sprays as compared with the effectiveness of the repellent sprays is most probably due to coverage. Inasmuch as all the toxic sprays kill by contact, good coverage is essential for good control.

One possible explanation for the poor results obtained with formula O, a water emulsion, is that rains may have removed enough of the toxic material to permit additional attack, with subsequent development and emergence. This theory is somewhat substantiated by the larger number of bark beetle galleries per square foot of bark found in this pile as compared with the pile sprayed with formula A (table 7). Formula A is both repellent and toxic to elm bark beetles.

As previously defined, normal galleries are those having one or more living larvae; for this reason the results of the repellent sprays based on emergence should be considered a more representative measure of their effectiveness than the results based on the number of egg galleries (table 6, last two columns).

Consideration must be given to another fact concerning the abovementioned log piles, and that is that the logs of the bottom tier in these piles were so shaded by weed growth that they were too green for bark beetle attack 5 months after they were cut. These logs might be susceptible to bark beetle attack during a second flight season.

COST OF APPLICATION

It is difficult to present data concerning cost in general, as much depends on the conditions connected with each problem. Careful notes, however, were kept on the treatment of the above-mentioned wood piles, and these data are presented in table 8.

TABLE 8.—*Cost data on spraying 1-cord piles of elm wood*

Spray formula	Total bark area treated	Total spray used	Total cost of spray	Time required to apply spray
	Square feet	*Gallons*	*Cents*	*Minutes*
A (repellent)	608	2.45	49	6
G (repellent)	604	2.80	78	7
A (toxic)	703	2.65	53	7
O (toxic)	775	3.00	54	8

SUMMARY

Naphthalene flakes, crude orthodichlorobenzene, chlorinated naphthalene, diphenyl flakes, and pentachlorophenol were tested for their repellency or toxicity to the two principal elm bark beetles, *Scolytus multistriatus* and *Hylurgopinus rufipes*.

The cost per gallon of the sprays considered in this circular ranged from 12 to 55 cents.

From 5 to 10 elm logs were sprayed for each toxicity experiment, an equal number being observed as checks. All lots were stored in a screened outdoor cage and emergence determined. For the repellency tests the logs were sprayed and left exposed to attack and later stripped of bark so that the egg galleries could be counted.

Bark moisture ranging from 30 to 139 percent, compared with dry weight, was found not to affect the results of these sprays.

Best results were obtained from the spraying when the air temperatures were above 50° F. (10° C.).

The age of the bark beetle brood made no great difference in the toxic effect of the sprays.

Based on emergence per 100 mm. of egg gallery, reductions over checks for these mixtures ranged from 68.4 to 100 percent.

Based on the number of egg galleries per log, a number of the mixtures gave reductions over checks ranging from 75 to 100 percent. These repellent treatments were exposed to weather from 7 to 52 weeks and to bark beetle attack from 4 to 20 weeks.

Repellent sprays were found effective for the entire active season.

Certain of the mixtures applied to tightly staked, 1-cord piles of elm logs under field conditions gave good repellency and kill.

From 2.45 to 3 gallons of spray were used to treat log piles having between 604 and 775 square feet of bark surface. The cost of spray materials to treat 1 cord of elm wood ranged from 49 to 78 cents.

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